5. Calibration Procedures

The following specifies the stepwise procedure for calibrating heat-flux sensors with reference to the transfer standard radiometer using the VTBB.

5.1 Pre-Calibration inspection

The continuity of the sensor signal leads is checked and the value of the resistance, using a multi-meter, is recorded. The condition of the high absorptance coating on the sensor surface is inspected. If the conditions indicate the need for repainting, the customer is informed. The surface is not repainted at NIST.

5.2 Additional test equipment

Heat-flux sensors have a wide range of configurations. Standard mounting blocks and sensor holders are readily available for mounting the 25 mm diameter Gardon and 5 mm diameter Schmidt-Boelter sensors. However, some sensors may require special mounting arrangement. If so, a suitable accessory is designed for fabrication in advance of the calibration. The cooling requirements for the sensor, and the need for any special instruments like amplifiers, thermometers etc., are checked.

5.3 Calibration

Appendices A and B detail the heat-flux sensor calibration procedure. The reference standard radiometer (ESR) requires self-calibration prior to testing. Appendix A describes the self-calibration procedure. The self-calibration, at a radiant power of approximately 920 mW, is necessary to be consistent with the radiometer settings during calibration and use. Self-calibration at other radiant powers within the range of the radiometer is acceptable as long as the instrument settings during calibration and use are identical. Appendix B describes the heat-flux sensor calibration procedure at about 8 to 10 heat flux levels covering the calibration range. Table 4 shows the required temperature settings of the VTBB and corresponding heat-flux level at the sensor, for different locations of the sensor from the blackbody aperture.

Table 4. Heat-flux values at sensor location for different blackbody temperatures

***X* = 12.5 mm**		***X* = 62.5 mm**		***X* = 140 mm**	
Temperature [K]	Heat-flux [kW/m^2]	Temperature [K]	Heat-flux [kW/m^2]	Temperature [K]	Heat-flux [kW/m^2]
1573	8.84	1823	5.09	1073	0.32
1773	13.07	1963	7.43	1573	1.30
1973	18.91	2108	9.72	1973	2.99
2123	24.19	2233	11.91	2273	5.11
2273	30.88	2373	14.94	2473	7.04
2273	30.91	2573	20.38	2573	8.21
2373	36.19	2773	27.08	2673	9.52
2453	41.17				
2553	47.31				
2653	54.81				

X: Distance from blackbody aperture to sensor location

The heat-flux values listed are approximate and are useful in deciding the optimum sensor location from the blackbody aperture to cover a desired calibration range. The actual heat flux values may vary over the long term because of aging of the graphite heating element and other factors. However, this variation will have no effect on the actual calibration. The transfer standard radiometer measurements give the actual heat flux values. Prior to calibrating the test sensor, it is desirable to perform a calibration on the reference Schmidt-Boelter sensor described in Sec. 4.4.

5.4 Post-Calibration inspection

The heat-flux sensor is removed from the test installation after disconnecting the signal lead, thermocouple lead, and cooling water. The signal lead continuity and the resistance are checked, as well as the condition of the high absorptance coating to ensure that it did not changed during the calibration process.

5.5 Data reduction

Appendix C gives the data reduction procedure. An EXCEL spreadsheet or other standard statistical software may be used. The measured heat flux is calculated from the measurement equation,

$$E_{\mathrm{c}} = \frac{V_{\mathrm{s}} - V_{\mathrm{d}}}{S} \ , \tag{6}$$

where V_{s} is the measured sensor signal in V or mV, V_{d} is the measured dark signal of the sensor in V or mV, and S is the measured responsivity of the heat-flux sensor expressed in mV/(W/cm^2) or mV/(kW/m^2). The regression curve fit for the data is generally linear with regression factors close to unity. In some cases, a small degree of non-linearity may appear at low heat flux levels, when calibrating with the sensor located close to the blackbody aperture. This non-linear effect is due to argon purge-gas flow effects, and reduces with increasing heat flux. The calculated responsivity depends largely on the readings at high heat flux levels.

5.6 Calibration report

A calibration report is prepared as per the standard format, shown in Appendix D, including any special comments specific to the calibration and measurement uncertainties.